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TITLE:	INTRODUCTION TO METAL CORED WIRES

CONTENTS:

AN ISO 9001:2000 COMPANY

Dwekam Electrodes Private Limited

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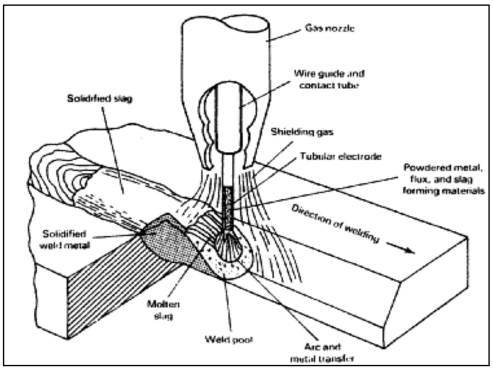
1.0 INTRODUCTION

Metal cored wire is a tubular electrode consists of thin metal sheath and a core with various powdered materials, primarily iron along with deoxidizers, arc stabilizers and alloying elements. Unlike flux cored wires, metal cored wires do not form a covered slag on the weld bead. The core contributes almost to the deposited weld metal.

Though the construction of metal cored wire is similar to flux cored wires, they are much closer to solid wires in performance and usability. Such resemblance has classified metal cored wires under **AWS SFA 5.18** (*Specifications for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*). They are also classified in other material documents for low alloy steel (**AWS SFA 5.28**: *Specifications for Low Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*), stainless steel wires, surfacing materials, etc.

In solid wire the entire cross section carries the welding current. The molten droplets are large and the mode of metal transfer is mainly globular. While metal cored wire, the current concentrate on the outer metal sheath that creates a broader bowl-shaped arc cone. It facilitates spray transfer with finer droplets and a less turbulent weld pool. The process is look-alike of GMAW & gas-shielded FCAW processes, schematically shown in figure-1.



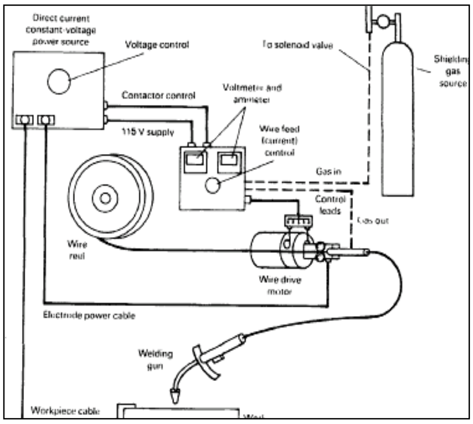


Figure-1: Schematic representation of metal cored arc welding process

2.0 USE OF METAL CORED WIRES

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Any fabrication industry uses GMAW or FCAW wires can rely on metal cored wires. Altering the composition of the metal powders in the core, metal cored wires are designed to meet a huge variety of applications. Both carbon steel and low alloy steel wires are formulated for structural steel, weathering steel, nickel, chrome-moly, medium alloy steel, etc.

Among the various scope of use of metal cored wire, few applications namely are-

- Single pass solid wire welds more than 50mm long.
- Multiple pass robotic or automatic welding.
- Solid wire in flat & horizontal positions where spray transfer is being used.
- Many gas shielded flux cored and some submerged arc applications.
- Other various applications based on welding cost & quality (especially for poor joint fit up, bead appearance, burn through, etc.)

For the same wire diameter, metal cored wires operate at much higher speeds than solid wire. With increased travel speeds, the deposition rate is increased by almost 25 to 30%.

Welding of thinner materials (3mm and below) is difficult with solid wires for “deep finger” type penetration (Figure-2a). The spray transfer for metal cored wire promotes improved travel speeds and a spread-bead without burn through.

Metal cored wires also provide better sidewall fusion while maintaining good penetration. This penetration profile (Figure-2b) bridges gap better, offer better tolerance to tracking errors and helps to eliminate burn through as well as cold lap. This is particularly important in mechanized & robotic welding where there is no welder to compensate for small tracking errors. Even if the operator does not hold the arc directly at the point, or if the adjoining parts have less optimal fit up, the burning characteristics of the wire compensate the variation and provide an acceptable joint.

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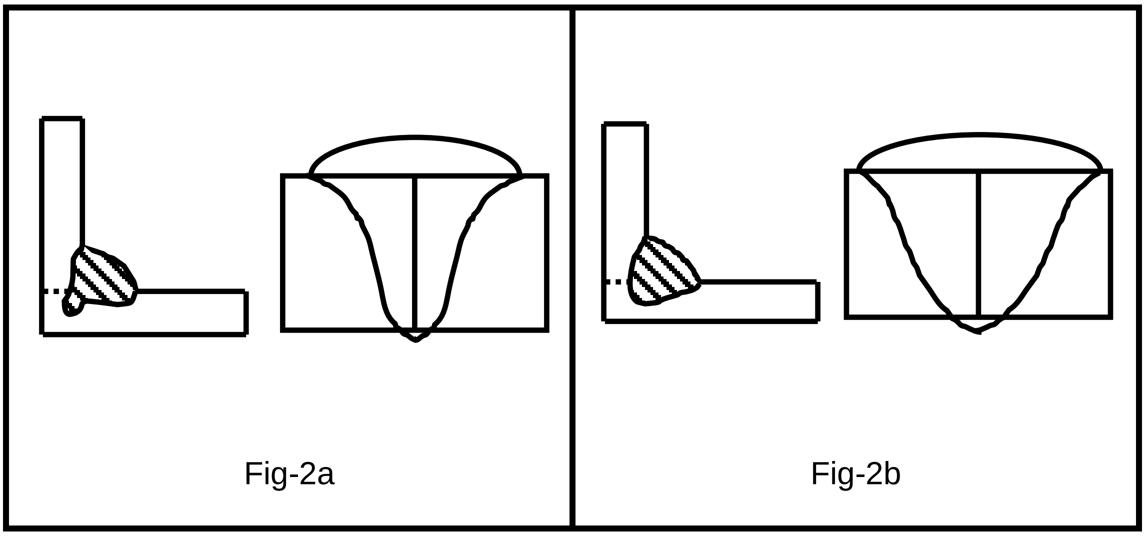

Figure-2: Nugget profile along the cross section of a weld bead made with a) solid wire & b) metal cored wire. Solid wire shows “deep finger” penetration.

3.0 SPECIFICATION OF FEW METAL-CORED WIRES

3.1 AWS/ SFA 5.18 (Chemical requirements)

Wire	Sh. gas	C	Mn	Si	S	P	Cr	Ni	Mo	V	Cu
E70C-3X	M or C	0.12	1.75	0.90	0.030	0.030	-	-	-	-	0.50
E70C-6X	M or C	0.12	1.75	0.90	0.030	0.030	-	-	-	-	0.50

Note:

Single values shown in the table are maximum limits.

From the above weld metals Bend test is not required and Diffusible Hydrogen test is optional.

X: It shows the corresponding shielding gas with which the electrode is classified.

M: 80% Argon 20% CO_2 and C: 100% CO_2

(-): Indicates to be reported if intentionally added. Cr+Ni+Mo+V shall not exceed 0.50%.

3.2 AWS/ SFA 5.18 (Mechanical requirements)

Wire	UTS, MPa	YS, MPa	EL, %	CVN, Joules
E70C-3X	480	400	22	27 (at -18°C)
E70C-6X	480	400	22	27 (at -29°C)

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3.3 AWS/ SFA 5.28 (Chemical requirements)

Wire	Type	C	Mn	Si	S	P	Cr	Ni	Mo	Cu
E90C-D2	Mn - Mo	0.12	1.0-1.9	0.90	0.030	0.025	-	-	0.40-0.60	0.35
E70C-B2L	Cr - Mo	0.05	0.40-1.0	0.25-0.60	0.030	0.025	1.0-1.50	0.20	0.40-0.65	0.35
E80C-B2	Cr - Mo	0.05-0.12	0.40-1.0	0.25-0.60	0.030	0.025	1.0-1.50	0.20	0.40-0.65	0.35
E80C-B3L	Cr - Mo	0.05	0.40-1.0	0.25-0.60	0.030	0.025	2.0-2.50	0.20	0.90-1.20	0.35
E90C-B3	Cr - Mo	0.05-0.12	0.40-1.0	0.25-0.60	0.030	0.025	2.0-2.50	0.20	0.90-1.20	0.35
E80C-Ni1	Ni	0.12	1.50	0.90	0.030	0.025	-	0.80-1.10	0.30	0.35
E70C-Ni2	Ni	0.08	1.25	0.90	0.030	0.025	-	1.75-2.75	-	0.35
E80C-Ni2	Ni	0.12	1.50	0.90	0.030	0.025	-	1.75-2.75	-	0.35
E80C-Ni3	Ni	0.12	1.50	0.90	0.030	0.025	-	2.75-3.75	-	0.35

Note:

Single values shown in the table are maximum limits.

From the above weld metals Bend test is not specified and Diffusible Hydrogen test is optional.

(-): Indicates value not mentioned

Shielding gas: Argon / 1-5% Oxygen

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3.4 AWS/ SFA 5.28 (Mechanical requirements)

Wire	Type	UTS, MPa	YS, MPa	EL, %	CVN, Joules
E90C-D2	Mn - Mo	620 (*)	540	17	27 (at -29°C)
E70C-B2L	Cr - Mo	515 (#)	400	19	Not required
E80C-B2	Cr - Mo	550 (#)	470	19	Not required
E80C-B3L	Cr - Mo	550 (#)	470	17	Not required
E90C-B3	Cr - Mo	620 (#)	540	17	Not required
E80C-Ni1	Ni	550 (*)	470	24	27 (at -46°C)
E70C-Ni2	Ni	480 (#)	400	24	27 (at -62°C)
E80C-Ni2	Ni	550 (#)	470	24	27 (at -62°C)
E80C-Ni3	Ni	550 (#)	470	24	27 (at -73°C)

Note:

Shielding gas: Argon / 1-5% Oxygen

(*): As-welded

(#): After PWHT at 620 ± 15 °C for 1 inch/ hour

4.0 ADVANTAGES OF METAL CORED WELDING (MCW) WIRES

4.1 Higher deposition rate

Carbon steel and low alloy steel metal cored wires are manufactured from carbon steel strip rolled & drawn to tube filled with metallic components. For a fixed current level, this leads to a higher current density in the cored electrodes compared to the solid wires. This phenomenon leads to higher melting rate and consequently higher deposition rate for metal cored wires (Figure-3).

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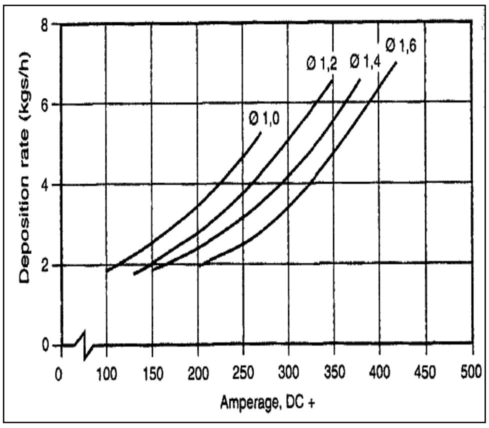

Figure: 3 Deposition rates of MCW wires with varying wire ∅ and current

The comparative deposition rate between 1.2mm diameter E70C-6M type metal-cored wire and ER70S-6 type solid wire is schematically shown in figure 4. Nearly 30-40% increase in deposition rate is observed with use of metal cored wires.

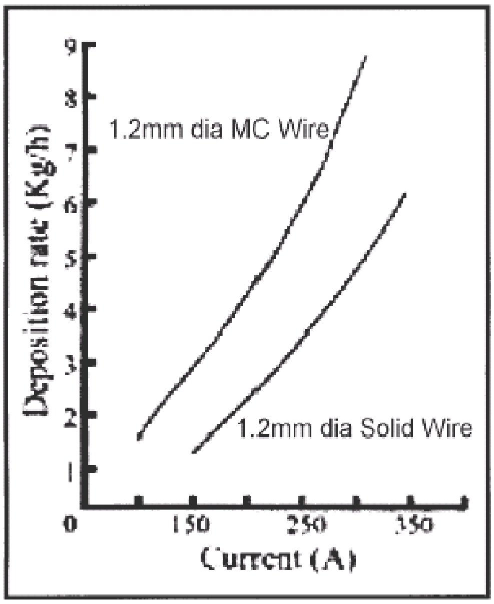

Figure: 4 Comparison of deposition rates of MCW wires with Solid wires

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4.2 Greater deposition efficiency

Deposition efficiency is defined as the percentage of usable metal deposits to the weight of wire consumed for making the deposit. It describes a measure of the "waste" during a welding process. Since little-to-no slag formation occurs in metal cored wires, an efficiency range of 91-95% for 1.2mm ∅ and 93-96% for 1.6mm ∅ is commonly achieved. It generally ranges between 90-95% for solid wires and 80-87% for flux cored wires.

4.3 Less slag on weld bead & little to no post-weld cleaning between pass

Compared to flux cored wires, metal cored wires contain arc stabilizers and little or no slag-forming components. The resulting weld deposit of a metal cored wire is thus very similar to solid GMAW wire, with only a few easily removable silicon islands on the weld surface. The least amount of slag eliminates the need of inter-pass cleaning and thereby imparts a significant influence on labour productivity. Nil-slag also reduces the risk of slag entrapment weld defects.

4.4 Low spatter

Argon-based shielding gas & arc stabilizers facilitate metal cored wires to burn with a stable and soft spray transfer. Almost 20-40% reduction in spatter is reported compared to CO_2-shielded flux cored wires. Decrease in labour & material cost is achieved in association with reduction in post-weld cleaning.

4.5 Reduction in the level of welding fumes

The fume generated with metal cored wire with the use of argon-based shielding gas is very low compared to the flux cored arc welding processes. The "low fume" standard is at par with the solid wires used with argon-based shielding gases.

4.6 Good bead shape & appearance

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Soft burning characteristics, low spatter & fume promote a comfortable weldability with metal cored wires. Better visibility reduces the chances of making a “over-welded” joint and thereby promote a significant potential to reduce the welding & the material cost.

4.7 Excellent side wall fusion

The spray-mode metal transfer in metal cored wires promotes a wider arc facilitating better side wall fusion and ability to join with higher root gaps.

4.8 Better root penetration compared to solid wire

The absence of “deep finger” penetration like solid wires (shown in figure-2), the metal cored wires promote better root penetration without burn through.

5.0 LIMITATIONS OF METAL CORED WIRES

5.1 Cost of consumables

The cost of metal cored wires is slightly higher than that of equivalent plain carbon steel variety. However, the gap is less in case of equivalent alloy steel wires.

5.2 Out of position welding

Although metal cored wire may be used for out of position welding at low amperages in a short-arc mode, generally they are not used for such applications except vertical down position. However, pulse welding has been reported to improve out of position welding characteristics.

5.3 UV-ray generation

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Argon shield during welding with metal cored wires generates a high intensity ultraviolet radiation. So, this is sometimes perceived as an operator comfort issue.

6.0 COMPARISON OF VARIOUS PROCESSES

The compiled summary on the comparison of various welding processes is given below in the Table-1.

Table-1: Comparison of technical data for various processes

	SMAW	GMAW	FCAW	MCAW
Deposition rate, kg/ hr	2.2	3.5	4.5	5.5
Deposition efficiency, %	65	89	85	95
Effective working hour, %	30	45	40	45
Arc Voltage, V	26	28	28	34
Welding Current, amp	180	240	280	350
Rework, %	4	4	3	3

SMAW: 4.0mm diameter electrode and GMAW/ FCAW/ MCAW: 1.6mm diameter wire

7.0 CONCLUSION

Metal cored wire causes a significant reduction in fume generation, eliminate/ reduce post weld cleaning, influence duty cycle of welder and improve deposition rate & efficiency.

It is true that in general, these wires are costlier compared to their equivalents of solid & flux cored wires. However, filler metals only make up 15 percent of a weld cost and gas is 5 percent. Labour accounts almost 80 percent of the total welding cost.

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Therefore, metal cored wire can far outweigh a small increase in consumables cost considering the benefits in productivity that can be accrued from the use of this process.

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